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Beneficial Microbes in Spaceflight or: How I Learned to Stop Worrying and Love the Bugs

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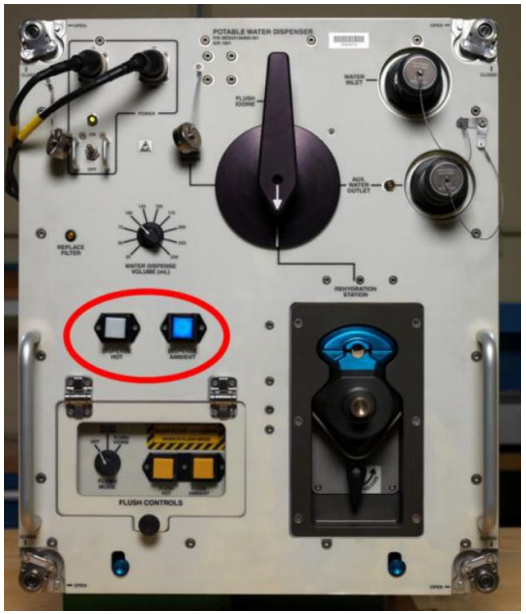
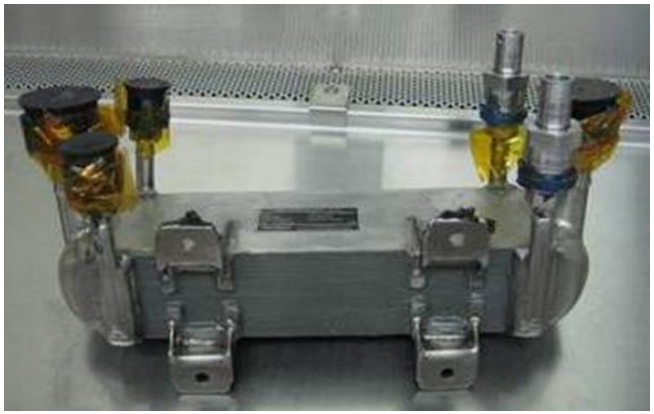
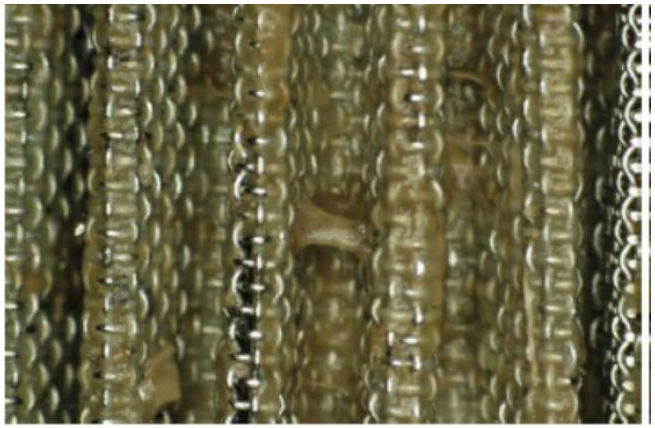
Background

- Microorganisms have been hitchhiking their way into space since the beginning of manned spaceflight
  - Apollo
  - Space Shuttle
  - ISS
- Typically considered a nuisance

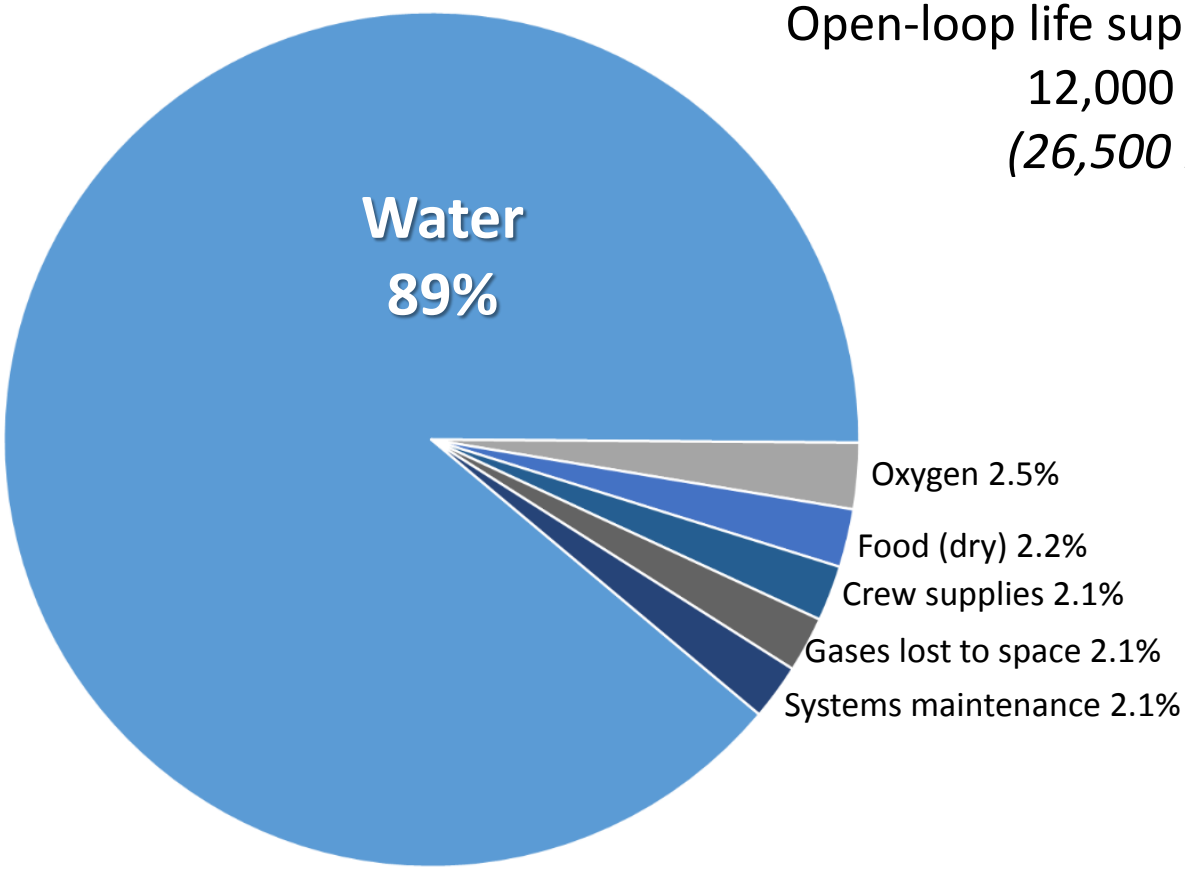






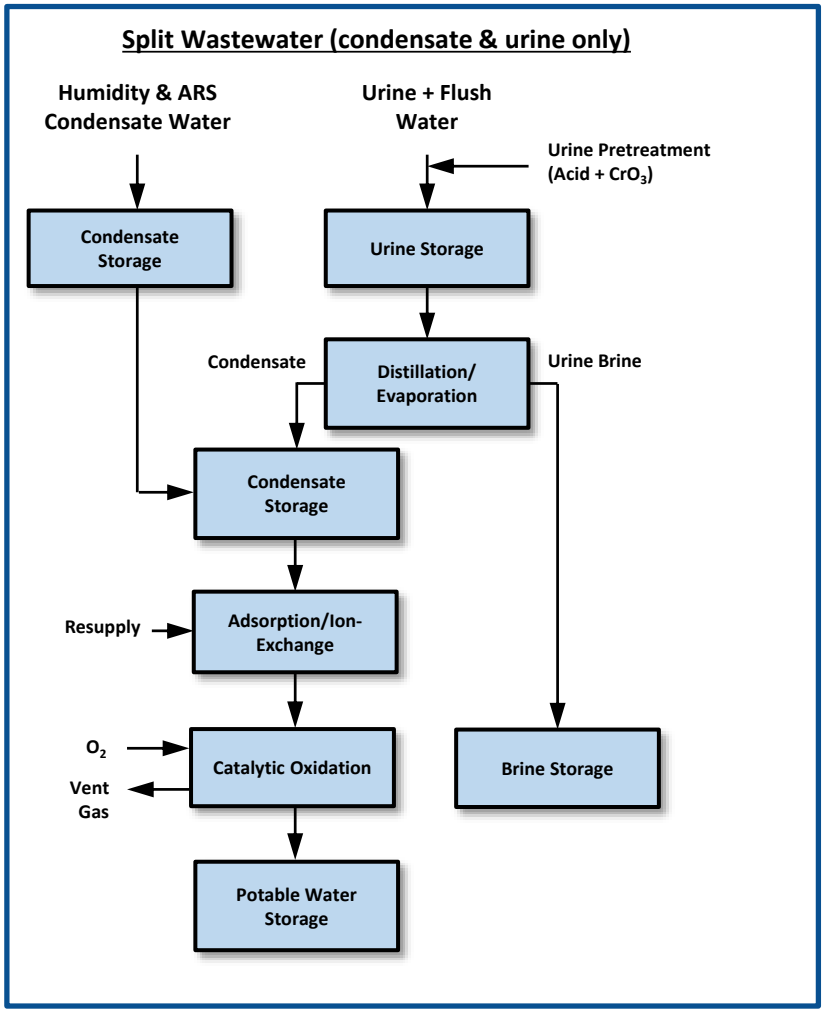
Life Support Requirements

Open-loop life support system resupply mass
12,000 kg/person-year
(26,500 lbs/person-year)

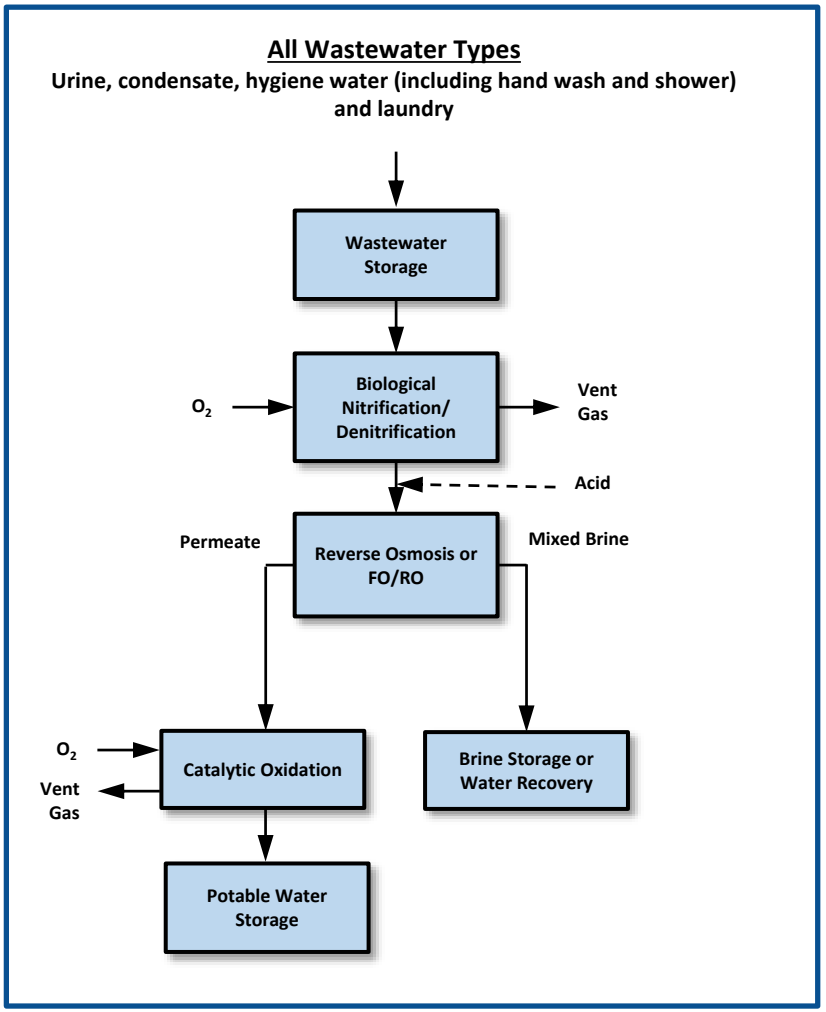


Water Recovery Architectures

Physiochemical Water Processor (ISS)



Biological Water Processor

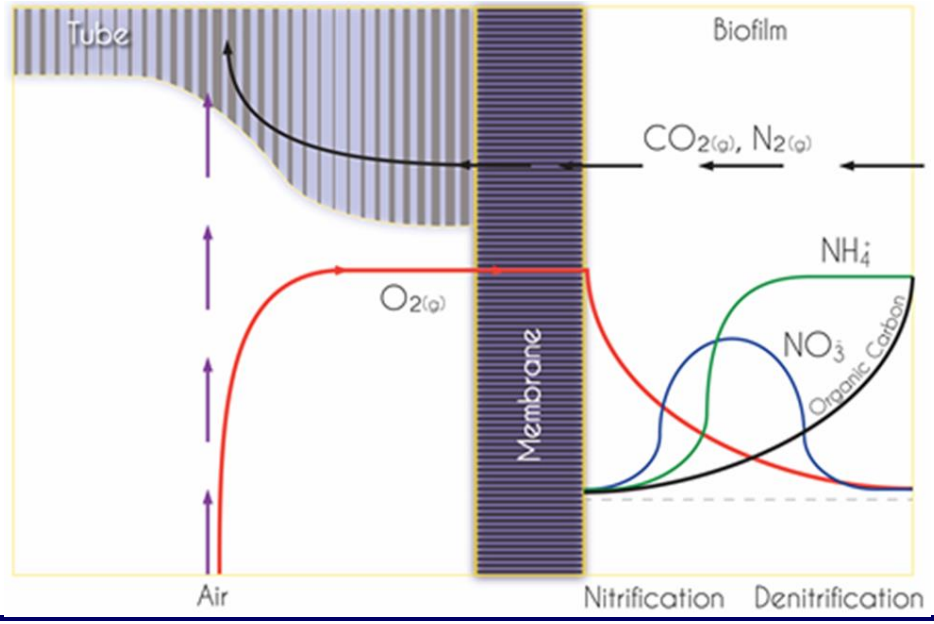


ARS = Atmosphere Revitalization System (CO_2 Reduction); FO/RO = Forward Osmosis/Reverse Osmosis

Biological Water Processor (BWP)

- Comprised of four (4) membrane aerated bioreactors (MABR)
- Tube-in-tube design
  - Oxygen module: contained membranes where the biological activities take place
  - Water shell: Contained the fluid and provided structural support to oxygen module

SND Process

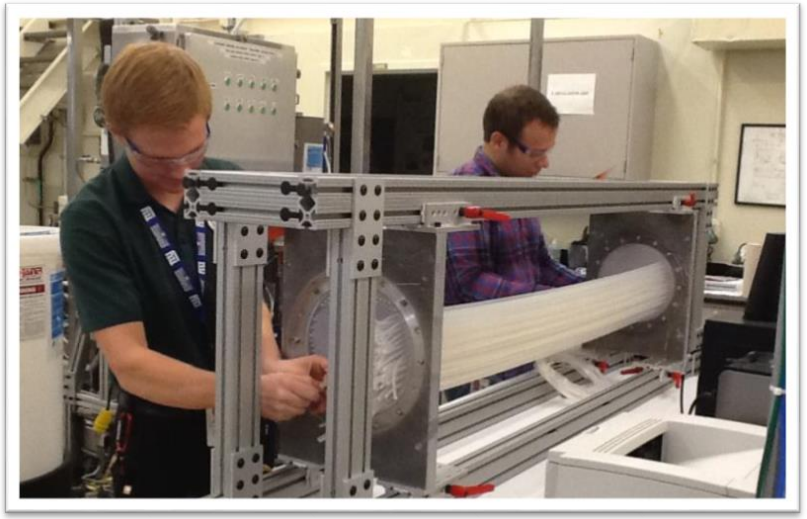

Tube
Biofilm
$CO_{2(g)}$, $N_{2(g)}$
NH_4^+
$O_{2(g)}$
NO_3^-
Organic Carbon
Membrane
Air
Nitrification
Denitrification

Test Summary

- BWP operated for 286 days in a four reactor configuration
  - 84% TOC removal
  - 56% Ammonium conversion
- Took 71 days to go from inoculation to full operations (i.e. process all wastewater components
  - Could that duration reduced?

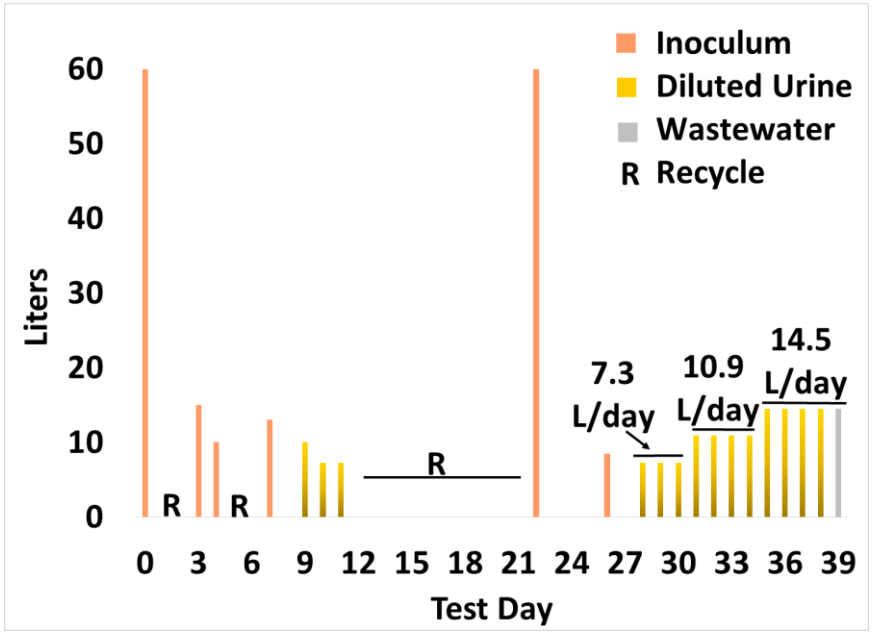
Rapid Start Evaluation

- Goal: to reduce the time from inoculation to steady-state operations
- Two components to testing:
  - Membrane modification evaluation
    - Chemically etched tubing
    - Conditioned tubing
  - Inoculation protocol validation
    - Diluted vs non-diluted inoculum

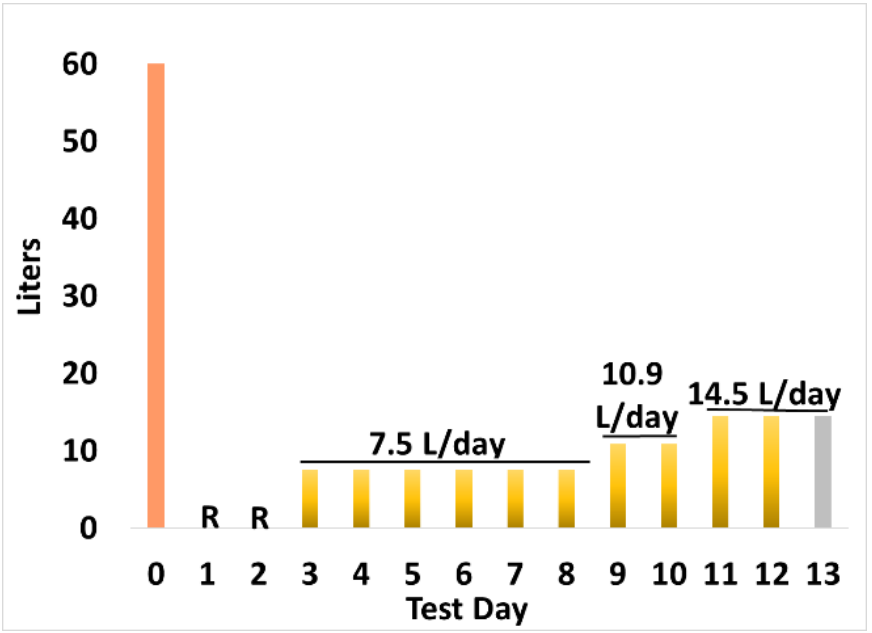


Step	Volume fraction (% added of daily feed volume, 14.5L)	Influent composition	Volume	Feed Rate
	100%	Filtered inoculum	60 liters total	0 (in recycle)
First	50%	Urine in DI	7.5 L total (1.14L urine)	5.0 ml/min
Second	75%	Urine in DI	10.9L total: (1.7L urine)	7.6 ml/min
Third	100%	Urine in DI	14.5L total: (2.275L urine)	10.1 ml/min
Fourth	100%	Full wastewater combined stream	14.5L combined wastewater	10.1 ml/min

Etched vs Conditioned Membranes

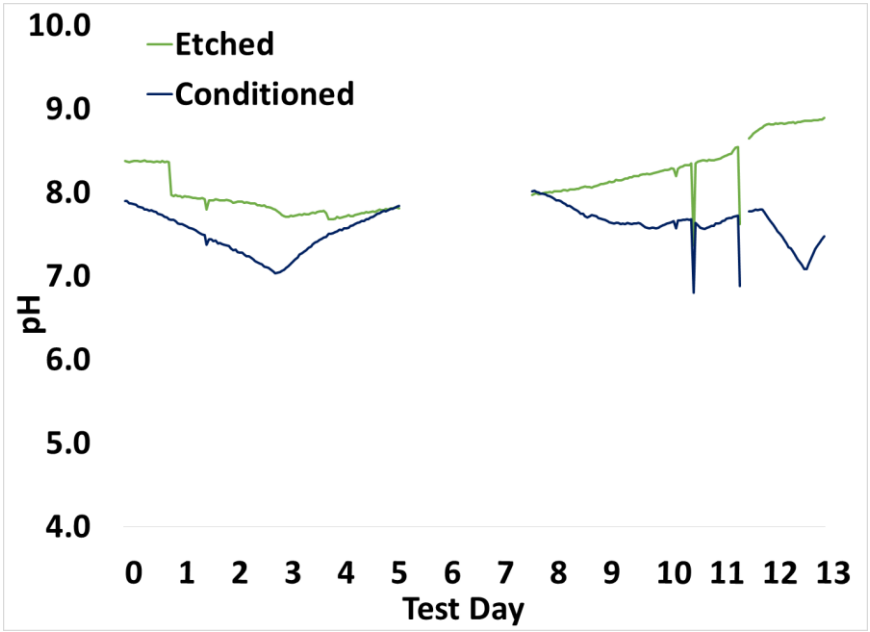


Etched

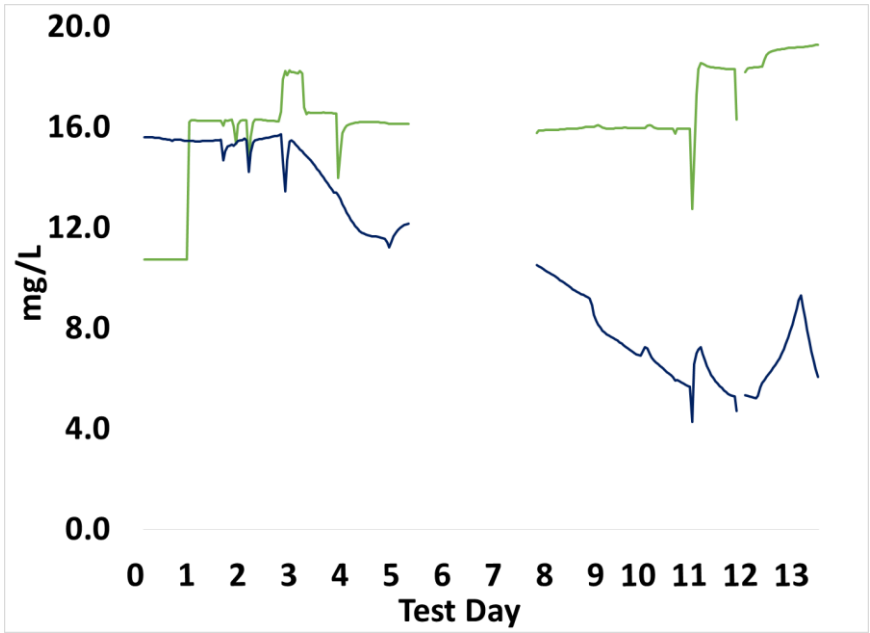


Conditioned

pH and DO: Etched vs. Conditioned



pH



DO

Summary and Next Steps

- Reduced duration of inoculation from 71 to 13 days
- Further work
  - Evaluate physical characteristics of membranes
  - Repeat rapid inoculation protocol in subsequent bioreactor tests for reproducibility
  - Evaluate surface area loading rates
  - Develop design specifications for an on-orbit MABR

Physiological Changes in Spaceflight

- Bone loss
- Muscle atrophy
- Vision issues
- Depressed immunity
  - Virus reactivation

Hosts and Microbes on ISS

- **<u>Microbiome</u> (Hernan Lorenzi, J Craig Venter Institute)** – Evaluating changes in the microbiome and immune status of nine astronauts during spaceflight missions.

Impact of Long-term Space Travel on an Astronaut's Microbiome

- **Background:** Very limited information is available on potential changes in the astronaut microbiome. Current evidence suggests these changes could have major impact on crew health.
- **Research Questions:** What are the changes in the crew microbiome and could they have health implications?
- **Status:** This study designed to gather information on changes in the crew microbiome before during and after spaceflight missions. Samples include nasal, fecal, multiple skin, and environmental sites. Sample size is 9 astronauts. Samples continue to be batched and sent to the PI's institution for analysis. Sample collection is due to finish in August 2016.
- **Benefit:** While this study is a small overall sample size, these samples should provide a foundation from which (a) definition of any potential crew health problems can begin and (b) follow up studies can be solicited.

Microbiome Experiment Design

Pre-Flight	In-Flight**	Post-Flight
Subject Swabs L-240, L-150, L-90, L-60	Subject Swabs FD7, FD90, R-14	Subject Swabs R+1/3, R+30, R+60
Gastrointestinal Sampling L-240, L-150, L-90, L-60	Gastrointestinal Sampling (optional) FD7, FD90, R-14	Gastrointestinal Sampling R+1/3, R+30, R+60
Blood Draw* L-60	Blood Draw** FD7, R-1	Blood Draw* R+0, R+180
Saliva Collection*** L-240, L-150, L-90, L-60	Saliva Collection*** FD7, FD90, R-14	Saliva Collection*** R+1/3, R+30, R+60, R+180
	Perspiration Swabs FD7, R-14	
	ISS Surface Swabs FD7, R-14	
	Potable Water Collection R-14 (once per increment)	

*Shared stick with Med Ops

**If possible, sessions will occur concurrently with existing medical/research activities

***Each session consists of a 7-day period with a sample collection performed every other day

Thank you!